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SPO PRICE \$ \_\_\_\_\_

BEST PRICE(S) \$ \_\_\_\_\_

Hard copy (HC) 1.00Microfiche (MF) .50

1965 July 65

N67 10216

(ACCESSION NUMBER)

(PAGES)

(NASA CR OR TMX OR AD NUMBER)

(THRU)

(CODE)

(CATEGORY)

Translation of "Dinamika atmosfery i serebristyye oblaka"  
Meteorological Investigations. Noctilucent Clouds  
(Meteorologicheskiye Issledovaniya. Serebristyye Oblaka).

IGY Program, Section II, No. 12,  
Izdatel'stvo Nauka, pp. 88-91, Moscow, 1966

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON

OCTOBER 1966

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## ABSTRACT

The report considers the existing data on the dynamic processes in the upper atmosphere. The defining process for the atmosphere mixing at the altitudes of 60-100 km is the process of an intensive large-scaled turbulent mixing. It is stated that the dust layer in the noctilucent cloud zone cannot be stable. The turbulent mixing hinders the formation of a narrow stable dust layer at the mesopause level and promotes the formation of a cloud layer of ice origin.

In a discussion of the problems involved in the hypotheses of the origin of noctilucent clouds it is necessary to take into account the character of atmospheric dynamics in the region of the upper mesosphere and lower thermosphere (60-100 km), because an allowance for this factor may shed additional light on the nature of these clouds. /88\*

We will consider two well-known and firmly established facts: noctilucent clouds are always observed in a narrow layer with rather clearly defined boundaries in the region of heights 75-90 km in the zone of the temperature minimum (mesopause); intense movements usually are always recorded in the zone of

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\*Numbers given in margin indicate pagination in original foreign test.

noctilucent clouds. The latter fact, although recognized by all investigators, is immediately lost from sight as soon as the nature of noctilucent clouds is considered.

Our knowledge of the dynamics of the high layers of the atmosphere has been considerably supplemented in recent years. In particular, it has been clarified that the decisive factor in atmospheric mixing at the heights with which we are concerned (60-100 km) is a regime of intense large-scale turbulent mixing. This conclusion can be drawn from theoretical computations, based on the most general concepts of the relation of the intensity of molecular and turbulent mixing at different heights, as well as from numerous direct rocket experiments for investigation of winds in the high layers of the atmosphere (refs. 1-4), experiments on observation of artificial noctilucent clouds (refs. 5-7) and experiments in tracking (optical and radar methods) meteor trails in the "meteor zone" (refs. 8-14).

It is now clear (refs. 9 and 12-14) that turbulent formations in the region of heights 60-100 km are "plane eddies," attaining 100-200 km in diameter with a thickness of only 5-7 km. The plane of such eddies is oriented parallel to the earth's surface. The horizontal wind velocity in such eddies attains 100 m/sec or more, and the vertical component is 5-10 m/sec (ref. 2). The origin of eddy formations is possibly associated with wave movements of the internal and planetary waves type (ref. 12). It is important to note that the temperature stratification of the atmosphere in the layer 60-100 km (presence of a temperature inversion) has no effect on the intensity of mixing.

If the appearances of noctilucent clouds are in no way related to brief intrusions of large quantities of cosmic dust (meteor streams) (refs. 15 and 16), it is completely obvious that a stable narrow dust layer cannot be formed within

the broad region of mixing. The only possibility of the formation of such a layer, which frequently is present in the dense layers of the atmosphere, is that an intense temperature inversion suppresses both convective and turbulent transfer of air masses, with the result that particles of different impurities (dust, moisture, etc.) can accumulate under inversions. However, under conditions of a highly rarefied atmosphere the temperature inversion observed over a region of noctilucent clouds, as we already mentioned, does not possess such a property. Turbulent mixing in the considered region of the atmosphere, as follows from the mentioned studies, the list of which could be considerably expanded, not only does not attenuate with height, but intensifies considerably, attaining its maximum at heights of about 90-100 km, near the level of gravitational diffusion separation of gases. Since the rate of falling of dust particles at these heights is insignificant ("parachuting" regime),<sup>1</sup> the dust particles move along with all rapid air movements, and as a result are perforce carried throughout the entire layer of turbulent mixing.

In the light of these comments it is appropriate to raise the question: what specific conditions are necessary for the stable existence of a layer of particles of one type or another in the zone of intense mixing?

Under these conditions the existence of the layer is determined by three invariable conditions.

1. At definite heights in the atmosphere physical conditions must exist which differ from the conditions at adjacent heights, determining the nature

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<sup>1</sup>At heights of 90 km particles with a radius of 0.1 and 0.5  $\mu$  settle at a rate of 0.8 and 5 m/sec, respectively, and at a height of 80 km, 0.1 and 0.7 m/sec (ref. 17).

of the particles in a given layer (ionization, dissociation, condensation, etc.).

2. The particles reaching these heights as a result of mixing must acquire properties corresponding to the special physical conditions prevailing there. As a result, at the heights of this layer particles of different types (ions, atoms, "new" molecules, condensation products, etc.) will appear.

3. The particle, when leaving the region of special conditions by virtue of these same mixing processes, should lose the properties it has acquired (neutralization, association, evaporation, etc.).

It is obvious that failure to conform to any one of these conditions will mean that no layer is formed.

In approaching an evaluation of the validity of the hypothesis of the ice (water) nature of noctilucent clouds, it can be noted that water vapor particles satisfy all requirements formulated above.

In actuality, water vapor, upon entering the region of the temperature minimum (mesopause), under favorable conditions is condensed there and forms a visible cloud layer (ref. 18). Cloud particles exist, until air currents carry them beyond the limits of the condensation region. As soon as the cloud particles enter a region of higher temperatures (above and below the mesopause), they immediately are transformed into a gaseous state and vanish from this layer. It goes without saying that in this case the intensity of mixing does not result in washing out of the cloud layer, because the transformation of water vapor into ice and vice versa takes place virtually instantaneously upon reaching the appropriate critical temperature, and the boundaries of the layer therefore remain clearly defined.

Since circulation at great heights occurs by large-scale "plane" eddies, the cloud particles can persist for a rather long time in the region of the temperature minimum and there form the characteristic shapes of noctilucent clouds (ref. 19). The high velocities of air currents in the region of the mesopause naturally should cause high velocities of movement and the development of forms of noctilucent clouds. Nonuniformity of flow in the turbulent movement 190 apparently causes the structural details of noctilucent clouds.

Thus, it can be stated in summary that the continuous field of intense turbulence, affecting the entire region of the mesosphere and upper thermosphere to heights of about 100 km, is no obstacle to the formation of a cloud layer of ice origin in the region of the temperature minimum. Even the reverse can be said: mixing facilitates the formation of this layer, carrying into the region of the temperature minimum additional quantities of water vapor from the lower regions of the atmosphere. At the same time, turbulent mixing completely excludes the possibility of the formation of a narrow, stable dust layer at these heights.

In conclusion, still another comment may be made. If for any reason the condensation of water vapor and the formation of ice clouds is impossible in the atmosphere at the heights of noctilucent clouds, explanation of the visible layer requires that some other substance be sought. This new substance must satisfy the three conditions mentioned above. However, the possibility of replacing water vapor by any other substance suitable for the formation of noctilucent clouds in our opinion is extremely improbable.

# REFERENCES

1. Kellogg, W. W. The Upper Atmosphere. Trans. Amer. Geophys. Union, Vol. 44, No. 2, p. 413, 1963.
2. Manring, E., Bedinger, J. and Knoflich, H. Some Measurements of Winds and of the Coefficient of Diffusion in the Upper Atmosphere. Space Res., Vol. 2. Holland Publ. Co., Amsterdam, p. 1107, 1961.
3. Lenhard, R. and Wright, J. Mesospheric Winds from 23 Successive Hourly Soundings. Air Force Cambridge Res. Labs., Bedford, Mass., p. 81, 1963.
4. Lawrence, S. Monthly Wind Measurements in the Mesodecline over a One-Year Period. J. Geophys. Res., Vol. 67, No. 12, p. 4653, 1962.
5. Edwards, H. D. Justus, C. G. and Kurts, D. C. Evening Twilight Winds from 68 to 140 Kilometers for May 21, 1963. J. Geophys. Res., Vol. 68, No. 21, p. 6062, 1963.
6. Broglio, L. First Italian Experiment Using Sodium Cloud Technique. Space Res., Vol. 2, 1961. Holland Publi. Co., Amsterdam, p. 1140.
7. Matuura, Nobuo and Nagata, Takesi. Turbulent Conditions in the Upper Atmosphere. Rept. Ionosphere and Space Res. Japan, Vol. 16, No. 2, p. 185, 1962.
8. Gul'medov, Kh. Some Data on Turbulence of the Upper Atmosphere from Optical Observations of Meteor Trails at Ashkhabad and Kazan (Nekotoryye dannyye o turbulentnosti verkhney atmosfery po opticheskim nablyudeniya meteor-nykh sledov v Ashkhabade i Kazani). Geomagnetizm i Aeronomiya, Vol. 4, No. 4, p. 796, 1964.
9. Delov, I. A., Kashcheyev, B. L. and Borovich, L. Principal Characteristics of Turbulent Flux in the Earth's Atmosphere at Heights of 90-100 km

(Osnovni kharakteristiki turbulentnogo rukhu v atmosfere Zemli na vysoti 90-100 km). Dopovidi <sup>UKRSR</sup> AN , No. 8, 1964.

10. Savrukhin, A. P., Nasarova, L. I. and Yushkevich, E. S. Photographic Observations of the Drift of a Meteor Trail on 13 August 1961 (Fotograficheskiye nablyudeniya dreyfa meteornogo sleda 13 avgusta 1961 g.)  
Izv. AN Turkm. SSR, Seriya Fiz.-tekhn., Khim. i Geol. Nauk, No. 5, p. 128, 1963.
11. Nasyrova, L. I. and Savrukhin, A. P. Drift of Meteor Trails on the Basis of Visual Observations at Ashkhabad in 1959 and 1960 (Dreyf meteornykh sledov po vizual'nykh nablyudeniya v Ashkhabade v 1959 i 1960 gg.).  
Izv. AN Turkm. SSR, Seriya Fiz.-tekhn., Khim. i Geol. Nauk, No. 3, p. 27, 1963.
12. Khvostikov, I. A. Origin of Noctilucent Clouds and Temperature of the Atmosphere at the Mesopause (Proiskhozhdeniye serebristyykh oblakov i temperatura atmosfery v mezopauze). Transactions of the Sixth Conference on Noctilucent Clouds (Trudy VI soveshchaniya po serebristym oblakam), p. 7, Riga, 1961.
13. Grishin, N. I. Meteorological Conditions for the Appearance of Noctilucent Clouds (K voprosu o meteorologicheskikh usloviyakh poyavleniya serebristyykh oblakov). Transactions of the Sixth Conference on Noctilucent Clouds (Trudy VI soveshchaniya po serebristym oblakam), p. 107, Riga, 1961.
14. Dokuchayev, V. P. Brief Review of the Theory of Electrodinamic Meteorology of the Upper Atmosphere (Kratkiy obzor teorii elektrodinamicheskoy meteorologii verkhney atmosfery). IN: Ionospheric Research (Ionosfernyye issledovaniya), No. 13, p. 116, 1964.



15. Savrukhn, A. P. Investigation of Winds in the Lower Part of the Ionosphere on the Basis of Visual-Optical Observations of the Drift of Meteor Trails (Issledovaniye vetrov v nizhney chasti ionosfery po vizual'no-opticheskim nablyudeniya dreyfa meteornykh sledov). IN: Ionospheric Research (Ionosfernyye issledovaniya), No. 13, p. 158, 1964.
16. Teptin, G. M. Some Evaluations of the Parameters of Turbulence in the Meteor Region of the Atmosphere (Nekotoryye otsenki parametrov turbulentnosti meteornoj oblasti atmosfery). IN: Ionospheric Research (Ionosfernyye issledovaniya), No. 13, p. 162, 1964.
17. Bronshten, V. A. Nature of Noctilucent Clouds (O prirode serebristyykh oblakov). Transactions of the Sixth Conference on Noctilucent Clouds (Trudy VI soveshchaniya po serebristym oblakam), p. 141, Riga, 1961.
18. Ludlam, F. H. Noctilucent Clouds. Tellus, Vol. 9, No. 3, p. 341, 1957.
19. Mirtov, B. A. Meteor Matter and Some Problems of Geophysics of the High Layers of the Atmosphere (Meteornaya materiya i nekotoryye voprosy geofiziki vysokikh sloyev atmosfery). IN: Artificial Earth Satellites (Iskusstvennyye sputniki Zemli), No. 4, p. 118, 1960.